CHAPTER 12
EVIDENCE OF SUCCESS OF THE GK–12 APPROACH

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CHAPTER HIGHLIGHTS

- The GK–12 approach exemplifies STEM education project recommendations in recent policy documents.
- This chapter gives indicators for the success of the GK–12 approach in graduate student as well as K–12 Teacher and student populations.
- GK–12 Fellows strengthen their teaching, communication, research, and teamwork skills.
- The GK–12 approach has shown positive effects on Teacher understanding: an expansion of STEM content knowledge and skills, an increased awareness of STEM research, and elevated confidence in teaching STEM subjects.
- The GK–12 approach facilitates teacher professionalism by encouraging teachers to act as mentors and as part of a teaching and learning community.
- K–12 students—especially those underserved or underrepresented—involved in GK–12 projects show enhanced understanding of, and increased interest in, STEM content, skills, and careers.

RECENTLY PUBLISHED EDUCATION POLICY DOCUMENTS UNDERSCORE THE COMPONENTS OF SUCCESSFUL STEM PROJECTS at both the postsecondary and K–12 levels (National Research Council [NRC] 2011 and 2012, President's Council of Advisors on Science and Technology [PCAST] 2012). These documents emphasize systemic changes in STEM teaching and learning for all students, especially those of underserved and underrepresented groups.

For example, the recently released report from PCAST, *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics* (2012), makes the following recommendations to postsecondary educators to address the challenge of producing 1 million additional STEM college graduates over the next 10 years: (1) adopt empirically validated teaching practices, (2) advocate discovery-based research courses, and (3) encourage communication and partnerships among stakeholders. These are also goals of the GK–12 approach to training STEM graduate students, who are the gateway not only to cutting-edge science, but also to both educating undergraduates and communicating to the general public.

Similarly, on the K–12 front, recommendations have surfaced for teaching and learning. *Successful K–12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics* (NRC 2011) emphasizes the need for Teachers with "high capacity to teach in their discipline" (p. 20). Such capacity requires STEM Teacher professional development that (1) focuses on developing Teachers' pedagogical content knowledge; (2) facilitates teaching in the classroom; and (3) provides multiple and sustained opportunities. *A Framework for K–12 Science Education* (NRC 2012) recommends the need for K–12 learning experiences that engage students with fundamental questions about the world and provide opportunities to carry out scientific investigations and engineering design projects in the spirit that "scientists have investigated and found answers to those questions" (p. 9).

The proliferation of STEM partnership projects in the country, including the more than 300 funded through the NSF GK–12 program, and the numerous research publications resulting from these partnerships show that institutions embracing the GK–12 approach are successful at addressing these recommendations. However, lacking in the literature is any study that provides a synthesis of these publications and their quantifiable impacts on graduate students and GK–12 Teachers. This section addresses that need by documenting the evidence supporting the success of the GK–12 approach at meeting the pressing needs in STEM education.

A GK-12 Fellow from the University of Minnesota helps a student examine and dissect specimens.

ASSESSING OUTCOMES FOR GRADUATE STUDENTS

Graduate students are motivated to participate in STEM partnerships for both personal and professional reasons (Abt Associates, Inc. 2010). Many find it rewarding to participate in classroom activities and interact directly with K–12 students with the goals of instilling positive attitudes toward science and improving academic achievement. Working in K–12 classrooms also provides opportunities for graduate students to collaborate with Teachers, both to explore teaching practices and ways of enhancing student learning and to develop and fine-tune their own communication and presentation skills. Using a variety of assessment and evaluation techniques, a number of studies have documented the realization of these anticipated outcomes (Busch and Tanner 2006, Ferreira 2007, McBride et al. 2011, Mitchell et al. 2003, Moskal et al. 2007, Stamp and O'Brien 2005, Thompson et al. 2002, Trautmann and Krasny 2006). For example, nearly all (more than 90%) of former Fellows participating in a retrospective evaluation of NSF's GK–12 program indicated that participation in the STEM partnership improved their abilities in a variety of communication, teaching, and teamwork activities (Abt Associates, Inc 2010).

Potential outcomes for graduate students participating in STEM partnerships vary with the nature and structure of the project, but most fall within one or more of four general categories: (1) greater understanding and mastery of teaching skills; (2) enhanced communication skills, especially the ability to explain STEM concepts to nonspecialists and nonscientists; (3) increased teamwork and collaborative skills; and (4) improved research skills and understanding of the relevance of their research to society. Although evaluation activities and instruments may be designed to target a single anticipated outcome, multiple outcomes may be assessed simultaneously. For example, a single observational protocol might be used to evaluate both presentation skills (e.g., delivery, presence, organization) and related teaching skills (e.g., audience engagement, questioning skills, connecting to prior understanding).

Improved Teaching Skills and Knowledge of Pedagogy

As with GK–12 Teachers, Fellow–Teacher partnerships enrich the training of graduate students by providing opportunities to discuss and experiment with teaching practices aimed at enhancing student learning. As part of their involvement in STEM partnerships, Fellows often receive formal training in basic pedagogy, including learning and teaching styles, classroom management and assessment techniques, lesson plan design and development, and inquiry-based teaching methods. When this training is combined with practical training and experience in the classroom, participants develop an appreciation for the challenges faced by Teachers and become familiar with the culture of K–12 schools. Over time, they gain insights into the needs, interests, and capabilities of K–12 students and use this knowledge to design new STEM lessons. Consequently, it is not surprising that improved teaching skills and confidence with inquiry-based strategies are common outcomes of GK–12 projects nationwide (McBride et al. 2011, Stamp and O'Brien 2005, Thompson, Collins, et al. 2002, Thompson, Metzgar, et al. 2002, Trautmann & Krasny 2006). Additional evidence is provided in the results of the aforementioned retrospective analysis of the GK–12 program (Abt Associates 2010): More than 95% of the current Fellows responding to the survey agreed that their GK–12 experiences enhanced their ability to develop instructional materials, teach STEM concepts, and generate student interest in STEM activities. Similarly, an analysis of pre- and post-Fellowship survey data by McBride et al. (2011) indicated that Fellows' self-perceived skill levels increased in all areas surveyed, including teaching different grade levels, curriculum development, teaching methods, and assessment and management.

Enhanced Communication and Public-Speaking Skills

The potential for skill development through participation in STEM partnerships extends beyond teaching to include improved communication and public-speaking skills. Within the research and academic communities, there is a growing need for scientists to communicate and explain the nature and results of scientific research effectively to a variety of audiences (Baron 2010, Leshner 2007, Lubchenco 1998, NRC 2010 and 2011, Somerville and Hassol 2011). Yet, most graduate programs fail to require training that targets either communications skills or best practices for translating and relating science discoveries to nonscientists. Thus, STEM partnerships provide structured settings for graduate students to hone their communication skills and to practice sharing their research findings with persons outside their field. Moreover, the opportunity to improve communication skills is one of the top anticipated or expected gains cited by graduate students interested in participating in STEM partnerships (McBride et al. 2011). Comparable experiences are less common in more traditional graduate programs. Both master's and PhD students participating in a retrospective evaluation of the NSF GK–12 program reported a greater involvement in explaining STEM concepts to nontechnical audiences than their non-GK–12 peers (Abt Associates, Inc 2010). Fellows also were more likely to agree that their GK-12 experience and training improved their ability to explain STEM concepts to nonscientists.

Although it is common for projects to rely on self-reported data or self-perceived skill levels obtained through interviews and surveys in order to gauge the impact of a K–12 partnership on scientists, communication growth has also been measured with the use of more quantitative and objective criteria. Sevian and Gonsalves (2008) developed a rubric for assessing the quality of scientific explanations by graduate students. The rubric is based on the same structure used to describe effective teaching and includes an evaluation of the presenter's pedagogical and content knowledge, as well as the presenter's ability to integrate the two when explaining his or her research to audiences of nonscientists (Shulman 1987, Sevian & Gonsalves 2008). The protocol is applicable in a variety of contexts and can be used to measure communication growth (e.g., in a comparison of baseline vs. postintervention performance outcomes), to identify strengths and weaknesses in presentation skills of individual scientists, and to assess the effectiveness of new graduate training projects.

Similarly, Tankersley and colleagues (2012) developed a performance-based assessment of oral presentation skills (the Presentation Skills Protocol, or PSP) to track individuals' skill improvement and to assess the impact of the GK–12 experience on the communication skills of graduate students participating in the Integrated Science Teaching Enhancement Project at Florida Tech. The PSP focuses on 11 presentation skill sets: organization, accuracy, relevance, message, language, equity, delivery, technology, use of time, questions, and presence. It includes a detailed rubric that operationally defines each skill set at three categorical levels of competence: (1) proficient; (2) developing; and (3) needs attention. The PSP was used to provide students with regular and consistent feedback on the quality and effectiveness of their classroom and research presentations. The instrument is used to inform the design of professional development activities and training projects that target specific presentation skills.

However, use of the PSP alone did not guarantee communication growth or competence in the Fellows it assessed. Significant gains in most presentation skill areas were achieved only when a three-pronged approach was taken: (1) formal training was given in best practices and techniques for preparing and delivering presentations (e.g., semester-long courses or intensive professional development workshops focusing on communication skills); (2) frequent opportunities were provided to practice and hone presentation skills (e.g., presentations at professional meetings and informal science centers, as well as in K–12 classrooms); and (3) regular individualized and structured feedback was given (e.g., via the PSP).

Ability to Work Cooperatively on Teams

Graduate students in STEM partnerships must be able to work effectively on teams. STEM partnerships also rarely operate in isolation and are typically part of a larger project that includes multiple teams (e.g., a GK–12 project). As a consequence of their participation in the partnership, Fellows report that they gain collaborative skills and a better understanding of what it takes to be an effective partner. They value the skills and insights their partner contributes to the team. Within the GK–12 project, Fellows rank working as a team as one of the top benefits associated with their experience (Abt Associates 2010). Nearly a third of the Fellows in the University of Montana's GK–12 project (ECOS) identified improved interdisciplinary teamwork and collaboration as the greatest benefit of participating in the project (McBride et al. 2011). Research advisors have a similar perception of the effect of GK–12 experiences on participants' collaborative skills. More than two-thirds indicated that the experiences had improved Fellows' abilities to work on or lead a team (Abt Associates 2010).

Improved Research Skills and Better Understanding of the Relevance of Their Research to Society

STEM partnership experiences not only provide Fellows with practical training in teaching and science communication, but also contribute to their development as researchers. For example, graduate students participating in San Francisco State University's Science Education Partnership and Assessment Laboratory (SEPAL) GK–12 partnership reported that the pedagogical training and teaching experience they received improved the way they practiced science, broadened their view of scientists, and changed their perception of the role of scientists in K–12 science education (Busch and Tanner 2006). Other studies have reported that teaching fundamental and complex science concepts to K–12 students required the Fellows to take a "big picture" view of their research area and frame it in a context relevant to those students (McBride et al. 2011, Mitchell et al. 2003, Stamp and O'Brien 2005, Trautmann and Krasny 2006). They were also forced to consider the connections among science disciplines and reflect on the relevance of their own discipline to potential stakeholders. Thus, as a consequence of their participation in K–12 outreach, Fellows come to appreciate the importance of engaging in activities and concepts that are relevant to the lives of K–12 students. They reflect on the ways in which their work affects society, and they gain insights into strategies that broaden the impact of their research through education, outreach, and mentorship.

The benefits of graduate teaching experiences (including K–12 teaching partnerships) vis-à-vis the development of both Fellows' research skills and students' performance have been documented in several reports (French and Russell 2002, McBride et al. 2011, Trautmann and Krasny 2006). Although these findings are based largely on self-reported attributions and perceptions, Feldon et al. (2011) recently used a performance-based assessment tool to evaluate similar claims. They compared and evaluated written research proposals prepared by two groups of graduate students: those with both combined research and teaching responsibilities (as either a teaching assistant or a GK–12 Fellow) and those with only research responsibilities. Students who both taught and conducted research demonstrated greater improvement than their counterparts did in several research-related skills, including generating testable hypotheses and designing valid experiments.

ASSESSING K–12 TEACHER AND STUDENT OUTCOMES

Assessing the K–12 Teacher and student outcomes of a STEM project involves establishing goals and objectives as well as strategies to achieve them; however, such evaluation in the school setting is complex for several reasons. First, schools are distinct cultures that influence the outcomes of these partnerships. Second, each partnership is different, as are the participant groups, such as the Teachers and students that constitute them. Finally, STEM partnerships create changes in Teachers' and students' approaches to teaching and learning STEM, and since change is a process, it is difficult to measure and must be documented over time. Keeping in mind these complexities is critical to evaluating the outcomes of, and understanding the dynamics behind, any thriving partnership.

According to the Small Schools Project (2012), each K–12 school has a unique culture that includes not only the obvious demographics, curriculum, schedules, and policies, but also the social elements of communication, collegiality, support, and traditions that give the school its "personality." This multifaceted culture influences the context of the STEM partnership as well as its outcomes. In the current era of educational accountability, evaluative data sources such as test scores and surveys that generate numbers may shed light on how well a partnership is working. However, numbers tell only part of the story. Using a multiplicity of methods, research studies evaluating STEM partnerships depict the ability of these partnerships to foster positive changes in Teachers and students.

ASSESSMENT OF K–12 TEACHERS

A STEM partnership may facilitate changes in a Teacher, both as a professional and as a member of a learning community. Teachers may grow professionally in terms of knowledge about STEM topics, interest in teaching about them, and facility in orchestrating STEM lessons and other endeavors. Similarly, the collaborative aspect of the STEM partnership fosters an environment that provides Teachers access to resources as well as a voice within the STEM professional learning and research communities.

Enhanced Pedagogical Content Knowledge

Classroom teachers are professionals who possess a specialized type of knowledge termed *pedagogical content knowledge* (PCK), which includes knowledge, skills, and dispositions that influence the delivery of the enacted curriculum (Shulman 1987). STEM partnerships act as a catalyst in at least four domains of a teacher's PCK: (1) the development or expansion of science content knowledge; (2) the development or enhancement of skills; (3) an understanding of the nature of science, including awareness of cutting-edge research; and (4) the enhancement of the affective domains of confidence, enthusiasm, facility, and motivation (Gengarelly and Abrams 2008, Mitchell et al. 2003, Raju and Clayson 2011, Thompson, Metzgar, et al. 2002). An example of this catalytic effect displayed in all domains is demonstrated in a retrospective evaluation of the NSF-funded GK–12 program. The majority of the 740 Teachers who responded to the survey reported growth in one or more PCK domains, as is synthesized and encapsulated in Table 12.1.

Another STEM partnership, Columbia University's Summer Research Project, provided research experiences for middle and high school teachers from New York City's public schools. The partnership enhanced participating teachers' ability to communicate science to students (Silverstein et al. 2009). In the year prior to the project, students of participating teachers and students of nonparticipating teachers passed a New York State Regents science exam at the same rate, whereas three to four years after entering the project, participating teachers' students passed the Regents science exams at a rate that was 10.1% higher than that of nonparticipating teachers' students. This finding

Table 12.1: Teachers' Perceived Effect of STEM Partnerships on Enhancement of Pedagogical Content Knowledge (PCK)

Domains of PCK	To Some Extent	To Great Extent	Total
DEVELOPMENT OR EXPANSION OF SCIENCE CONTENT KNOWLEDGE			
Increased knowledge of content taught	46%	27%	73%
Expanded knowledge beyond content taught	42%	24%	66%
DEVELOPMENT OR EXPANSION OF SKILLS			
Increased manipulative activities in instruction	37%	37%	74%
Increased use of technology	32%	18%	58%
UNDERSTANDING THE NATURE OF SCIENCE			
Increased knowledge of what researchers do	34%	29%	63%
Awareness of cutting-edge research	36%	19%	55%
ENHANCEMENT OF AFFECTIVE DOMAINS			
Increased confidence in teaching STEM	31%	25%	56%
Increased confidence in using STEM resources	38%	24%	62%
Increased confidence in using manipulative activities	36%	29%	65%
Increased engagement with informal STEM activities	32%	20%	52%

SOURCE: ABT ASSOCIATES, INC. 2010.

echoes that in which GK–12 Teachers' perceived that the greatest impact of their experience was how the teaching Fellows' pedagogical competence enhanced their own abilities and improved their teaching (Abt Associates, Inc. 2010).

Furthermore, Thompson (2003) reported that involvement in the GK–12 initiative was a vehicle for exploring Teachers' understanding of the nature of science and scientific inquiry. In his cross-case analysis, Thompson explored the interactions between practicing Teachers and graduate teaching Fellows. He identified five scaled components of an inquiry framework: methodological, subjective, empirical, tentative, and creative. The portrayed range of each component on a continuum dictated whether the Teacher understood inquiry to be technical (rigid, more like scientific method) or substantive (fluid, more like science). Thompson's work suggested that involvement in the STEM partnership helped Teachers to improve their understanding of inquiry and the nature of science, their scientific literacy, and ultimately, their teaching. Similarly, a case study of four Teachers who participated in 225 hours of constructivist teaching that modeled pedagogical techniques through a GK–12 project showed that the positive effects are lasting. Two years after completion of the project, the observations of the Teachers' classrooms revealed that (1) personal relevance, (2) scientific uncertainty, (3) a critical voice, (4) shared control, and (5) student negotiation were integral parts of the Teachers' lessons (Beamer, et al. 2008).

Improved Access and Voice

Besides enhancing pedagogical content knowledge, STEM partnerships improve teachers' access to communities that provide professional development and support. For example, 136 of the principal investigators associated with the GK–12 program reported that their research communities provided participating Teachers with STEM consultation (95%), equipment and materials (75%), access to university resources (73%), opportunities to present at conferences (65%), and additional workshops and training (42%); clearly, this type of support is outside the average teacher's experience (Abt Associates, Inc. 2009).

Evaluating a GK–12 cohort group of 12 Fellows and 10 Teachers in the collaborative Graduate Teaching Fellows Project at Vanderbilt University, Thompson, Metzgar et al. (2002) found that one or more of three types of professional learning communities ensued from their partnership: (1) within-classroom communities that focused on collaborations between Fellows and Teachers in individual classrooms; (2) between-classroom communities in which multiple Fellows and Teachers would plan and prepare together; and (3) beyond-classroom communities in which Fellows were able to extend learning beyond the school setting.

A GK-12 Fellow from the Florida Institute of Technology uses an adult horseshoe crab to introduce biological, chemical and environmental concepts to elementary school students.

For example, a within-classroom community provided the arena for one Teacher to grow in her understanding of the nature of science. This was demonstrated by her willingness to discuss and debate knowledge of science concepts with the Fellow in the presence of students, hence providing students a model for taking intellectual risks and using argumentation to establish scientific understanding. Similarly, beyond-classroom communities provided workshop opportunities for Teachers to make professional connections with university mentors, sister schools, and community resources, as well as professional development opportunities for Teachers to branch out into areas such as presenting at a conference, publishing in a journal, and engaging in additional research experiences.

Summary of K–12 Teacher Assessment

Research on the impact of STEM partnerships on teachers shows two general indicators for assessment: growth in teachers' pedagogical content knowledge and growth in their willingness to form partnerships outside their school community. With regard to pedagogical content knowledge, evaluators should be mindful of growth in the following domains: (1) an expansion of content knowledge, both STEM knowledge for the classroom and current research knowledge to enrich classroom examples; (2) the development or expansion of skills such as integration of technology and authentic inquiry; (3) increased awareness of what researchers do and how they do it, as demonstrated in teachers' approaches to inquiry-based teaching and incorporating examples of cutting-edge research into their teaching; and (4) increased confidence teaching STEM, using resources and hands-on materials. As regards partnerships, evaluators should see teachers exhibiting indicators that they belong to a professional teaching and research community, collaborating with partners inside and outside the school setting to find intellectual support, equipment and materials, and workshop and training opportunities.

ASSESSMENT OF K–12 STUDENTS

Teachers' participation in STEM partnerships also fosters changes in their students. Interactions with STEM professionals may precipitate growth in students' STEM knowledge base, both intellectually and affectively. Students often increase their depth of understanding in STEM intellectual domains, such as content knowledge, technological skill, scientific reasoning, and the nature of science; however, growth in affective domains, such as increased confidence in STEM learning, as well as an increased interest in and appreciation of STEM topics, STEM professionals, and STEM careers (Abaid et al. 2011, Marx et al. 2006, Thompson and Lyons 2010) is also noted. The majority of the 740 Teachers surveyed retrospectively regarding the perceived effect of their GK–12 STEM partnership reported increases in their students' STEM intellectual and affective domains as indicated in Table 12.2 (Abt Associates, Inc. 2010).

Enhanced Understanding of STEM Content, Skills, and Careers

STEM partnerships enhance students' understanding of content knowledge, skills, and careers. Most often, this enhancement cannot be measured by a standardized test, because it is difficult to quantify. However, the aforementioned study by Silverstein et al. (2009) noted that partnership projects have the potential to raise students' science scores on standardized exams, and this may be particularly important to students coming from poverty or with learning disabilities. Powers et al. (2008) explored the learning of math students in grades 5 through 8 and their Teachers who were involved in one of several STEM partnership projects between Clarkson University and St. Lawrence County schools in northern New York. Students who were identified with poverty or a learning disability achieved statistically better on the New York math assessments if they had a Teacher who participated in a partnership. This effect could be related to students' increased interest in STEM topics because of the partnerships.

A study by Beghetto (2009) explores this idea. With regard to the nature of science, an important attribute of scientific thinking is the willingness to take risks. Although higher ability students are significantly more likely to engage in intellectual risk taking than those with lower ability, the GK–12 project data from Beghetto's study suggested that students' interest in science, creative self-efficacy, and perceptions of Teachers were uniquely and significantly related to their reports of intellectual risk taking. So STEM partnerships that increase interest, self-efficacy, and perceptions may influence achievement regardless of ability.

Table 12.2: Teachers' Perceived Effect of STEM Partnerships on Students' STEM Knowledge

Domains of STEM Knowledge	Minor Positive Impact	Major Positive Impact	Total
INTELLECTUAL			
Increased knowledge of STEM content	44%	52%	96%
Increased knowledge of STEM current research	50%	31%	81%
Increased analytical skills	59%	29%	88%
Increased knowledge of STEM careers	48%	43%	91%
AFFECTIVE			
Interest in learning STEM content at school	34%	60%	94%
Interest in taking advanced STEM courses	51%	26%	77%
Interest in extracurricular STEM activities	38%	29%	67%
Engagement in informal STEM activities	51%	30%	81%
Interest in STEM careers	48%	43%	91%

SOURCE: ABT ASSOCIATES, INC. 2010.

Furthermore, a unique component of the GK–12 STEM partnership model allows graduate students to assist with inquiry-based teaching, in turn leading to students enhancing their own understanding of the process of science. Gengarelly and Abrams (2008) noted that when 10 Fellows worked with high school science students on inquiry-based science projects for one academic year, students (1) gained an understanding of scientific concepts and the process of doing science; (2) increased their ability to formulate questions and derive answers; (3) enhanced their skills; and (4) improved their attitudes toward science.

In addition, students construct knowledge about STEM careers and STEM professionals. Thompson and Lyons (2010) studied the effects of the presence of engineers on high-poverty, low-performing upper elementary and middle school science students in the Engineering Fellows Project, a yearlong GK–12 project that partnered engineering students with the schools. The authors found significant differences in the perceptions of engineers between the group of 44 African-American students participating in the project and the matched control group that had not participated in the project. The participating students were more likely to perceive engineers as designing, presenting, and experimenting; the students also displayed greater awareness and understanding of various engineering fields.

Increased Interest in STEM Content, Activities, and Careers

Partnerships can increase student interest in STEM content, activities, and career paths, especially on the part of students in underserved, high-poverty populations. Many research studies document the positive effects of these partnerships. For example, Powers et al. (2008) note that students in grades 7–9 from some of the poorest and neediest rural K–12 schools in New York State who participated in either in-class K–12 problem-based learning projects or extracurricular VEX robotic projects recognized the importance of understanding STEM disciplines to solve real-world problems.

Similarly, as they facilitated a seven-module inquiry-based anatomy unit, a group of Fellows in medicine saw the interest and commitment of a group of high school biology students increase (Marx et al. 2006). At the onset of the unit, informal observations revealed that most of the students were apathetic toward science and school in general, planning to enter the workforce directly out of high school. On average, only 40% of these students took the SAT from 1996 to 2001, and less than half scored above a combined 1,000 on the verbal and math portions of the test. Because of the extended scientist–student interactions provided by the unit, the scientist stereotype was broken down, as indicated by an evident increase in the students' excitement in science and scientific careers. Students asked questions about "what a scientist actually does in a laboratory, what college is like, what graduate school is like, and how to become a scientist/engineer" (p. 147). Researchers noted the improvement in science understanding, but also the changes in the students' perceptions of careers in science.

These findings were echoed in other studies. Kinne et al. (2004) found that their GK–12 project reported a 50% increase in K–12 classroom students' interest in engineering and an 83% increase in their confidence to learn math and science. Mitchell et al. (2003) found that the presence of GK-12 Fellows in STEM courses provided many students with a role model "who is really enthusiastic, who is interesting, and is also a buddy to the kids" (p. 15). Teachers in Mitchell et al.'s study believed that the presence of positive role models would increase the likelihood that their students would attend college.

Summary of K–12 Student Assessment

Research on the impact of STEM partnerships on K–12 students shows two general indicators for assessment: growth in students' intellectual domains and growth in their affective domains. With regard to students' intellectual domains, evaluators should explore growth in areas of understanding of STEM content and current STEM research; knowledge of STEM professionals and what they do; and ability to use analytical, technological, and inquiry skills, such as intellectual risk taking, to approach STEM topics. For the affective domain, evaluators should also note the effect of STEM partnerships on students' interest in STEM topics and careers both inside and outside the classroom, as demonstrated by the students' engagement in classroom learning, advanced STEM courses, extracurricular STEM activities, and informal STEM activities. Although students have shown improvement in some standardized assessments in the state of New York (Powers et al. 2008, Silverstein et al. 2009), it is important to be mindful of the fact that most often standardized STEM content tests are not evaluating the indicators of growth we are hoping to enhance by STEM partnerships.

GK–12 APPROACH ANSWERS CALL FOR STEM REFORM

Science, mathematics, engineering, and technology (STEM) are fundamental aspects of our lives as "citizens, workers, consumers, and parents" (NRC 2011, p. 3). Recent indicators suggest that many students, particularly those from underserved and underrepresented populations, do not have the STEM background to successfully perform in STEM disciplines in college, compete for employment, or engage in personal and societal decisions. Furthermore, if the United States is to maintain its historical prominence in STEM fields, approximately 100,000 professionals will be needed in the next 10 years (NRC 2011, PCAST 2012).

Partnering STEM graduate students with students in K–12 schools not only benefits both sets of students, but also is a successful way to address the societal demand for a STEM-educated populace. Implementation of the GK–12 approach facilitates opportunities for STEM graduate students to broaden their experiences with research-based teaching practices, to enhance their communication skills, to work cooperatively, and to improve their research skills. Such outcomes have recently been recommended to the U.S. president (PCAST 2012) as a way to address the deficit of STEM undergraduates and produce the next generation of STEM professionals, particularly in underrepresented groups. In addition, GK–12 partnerships provide Teachers with opportunities to enhance their pedagogical content knowledge while belonging to supportive learning communities; this is a characteristic of professional development seen in STEM Smart Schools and proposed for successful STEM education (NRC 2011). Finally, GK–12 partnerships facilitate an enhanced understanding and interest in STEM content, skills, and careers on the part of K–12 students, a goal articulated in *A Framework for Science Education* (NRC 2012):

> *"The overarching goal of our framework for K–12 science education is to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology. (p. 1)"*

Given the research-based successes of the GK–12 approach, it makes perfect sense to implement that approach to improve postsecondary and K–12 education, foster scientific literacy, and train the next generation of STEM professionals.

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